T08D11 – Acid Base Topic HL Exam

Name KEY

1. Four aqueous solutions, I, II, III and IV, are listed below.

   I. 0.100 mol dm^{-3} HCl
   II. 0.010 mol dm^{-3} HCl
   III. 0.100 mol dm^{-3} NaOH
   IV. 0.010 mol dm^{-3} NaOH

   What is the correct order of **increasing** pH of these solutions?

   A. I, II, III, IV
   B. I, II, IV, III
   C. II, I, III, IV
   D. II, I, IV, III

* Explanations for questions #1-20 can be found on the SL exam KEY

2. Which methods will distinguish between equimolar solutions of a strong base and a strong acid?

   I. Add magnesium to each solution and look for the formation of gas bubbles.
   II. Add aqueous sodium hydroxide to each solution and measure the temperature change.
   III. Use each solution in a circuit with a battery and lamp and see how bright the lamp glows.

   A. I and II only
   B. I and III only
   C. II and III only
   D. I, II and III

3. Which **one** of the following species can act as both a Brønsted-Lowry acid and base in aqueous solution?

   A. CH_3COOH
   B. NO_3^-
   C. $H_2PO_4^-$
   D. OH^-

4. An aqueous solution of which of the following reacts with magnesium metal?

   A. Ammonia
   B. Hydrogen chloride
   C. Potassium hydroxide
   D. Sodium hydrogencarbonate

5. Which is a conjugate acid-base pair in the following reaction?

   $$HNO_3 + H_2SO_4 \rightleftharpoons H_2NO_3^+ + HSO_4^-$$

   A. HNO_3 and H_2SO_4
   B. HNO_3 and $H_2NO_3^+$
   C. HNO_3 and HSO_4^-
   D. $H_2NO_3^+$ and HSO_4^-

6. The equation for the reaction between nitric acid and sulfuric acid is shown below.

   $$H_2SO_4 + HNO_3 \rightleftharpoons H_2NO_3^+ + HSO_4^-$$

   Which species are acting as acids in this reaction according to the Brønsted-Lowry theory?

   A. H_2SO_4 and HNO_3
   B. H_2SO_4 and $H_2NO_3^+$
   C. HNO_3 and $H_2NO_3^+$
   D. $H_2NO_3^+$ and HSO_4^-

7. Which of the following is/are formed when a metal oxide reacts with a dilute acid?

I. A metal salt
II. Water
III. Hydrogen gas

A. I only
B. I and II only
C. II and III only
D. I, II and III

8. The pH of a solution is 2. If its pH is increased to 6, how many times greater is the $[H^+]$ of the original solution?

A. 3
B. 4
C. 1000
D. 10 000

9. Which equation represents an acid-base reaction according to the Lewis theory **but not** according to the Brønsted-Lowry theory?

A. $CO_3^{2-}(aq) + 2H^+(aq) \rightarrow H_2O(l) + CO_2(g)$
B. $Cu^{2+}(aq) + 4NH_3(aq) \rightarrow CU(NH_3)_4^{2+}(aq)$
C. $BaO(s) + H_2O(l) \rightarrow Ba^{2+}(aq) + 2OH^-(aq)$
D. $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$

10. Lime was added to a sample of soil and the pH changed from 4 to 6. What was the corresponding change in the hydrogen ion concentration?

A. increased by a factor of 2
B. increased by a factor of 100
C. decreased by a factor of 2
D. decreased by a factor of 100

11. Which substance can be dissolved in water to give a 0.1 mol dm^{-3} solution with a high pH and a high electrical conductivity?

A. HCl
B. NaCl
C. NH_3
D. NaOH

12. In which reaction is $H_2PO_4^-(aq)$ acting as a Brønsted-Lowry base?

A. $H_2PO_4^-(aq) + NH_3(aq) \rightarrow HPO_4^{2-}(aq) + NH_4^+(aq)$
B. $H_2PO_4^-(aq) + OH^-(aq) \rightarrow HPO_4^{2-}(aq) + H_2O(l)$
C. $H_2PO_4^-(aq) + C_2H_5NH_2(aq) \rightarrow HPO_4^{2-}(aq) + C_2H_5NH_3^+(aq)$
D. $H_2PO_4^-(aq) + CH_3COOH(aq) \rightarrow H_3PO_4(aq) + CH_3COO^-(aq)$

13. The pH of solution **X** is 1 and that of **Y** is 2. Which statement is correct about the hydrogen ion concentrations in the two solutions?

A. $[H^+]$ in **X** is half that in **Y**.
B. $[H^+]$ in **X** is twice that in **Y**.
C. $[H^+]$ in **X** is one tenth of that in **Y**.
D. $[H^+]$ in **X** is ten times that in **Y**.

14. When the following 1.0 mol dm^{-3} solutions are listed in increasing order of pH (lowest first), what is the correct order?

(A) $HNO_3 < H_2CO_3 < NH_3 < Ba(OH)_2$
B. $NH_3 < Ba(OH)_2 < H_2CO_3 < HNO_3$
C. $Ba(OH)_2 < H_2CO_3 < NH_3 < HNO_3$
D. $HNO_3 < H_2CO_3 < Ba(OH)_2 < NH_3$

15. Which substance, when dissolved in water, to give a 0.1 mol dm^{-3} solution, has the highest pH?

A. HCl
B. NaCl
C. NH_3
(D.) NaOH

16. Lime is added to a lake to neutralize the effects of acid rain. The pH value of the lake water rises from 4 to 7. What is the change in concentration of H^+ ions in the lake water?

A. An increase by a factor of 3
B. An increase by a factor of 1000
C. A decrease by a factor of 3
(D.) A decrease by a factor of 1000

17. Which change in $[H^+]$ causes the biggest increase in pH?

A. A change in $[H^+(aq)]$ from 1×10^{-3} to 1×10^{-2} mol dm^{-3}
B. A change in $[H^+(aq)]$ from 1×10^{-3} to 1×10^{-4} mol dm^{-3}
C. A change in $[H^+(aq)]$ from 1×10^{-4} to 1×10^{-2} mol dm^{-3}
(D.) A change in $[H^+(aq)]$ from 1×10^{-4} to 1×10^{-6} mol dm^{-3}

18. Which methods can distinguish between solutions of a strong monoprotic acid and a weak monoprotic acid of the same concentration?

I. Add magnesium to each solution and measure the rate of the formation of gas bubbles.
II. Add aqueous sodium hydroxide to each solution and measure the temperature change.
III. Use each solution in a circuit with a battery and lamp and see how bright the lamp glows.

A. I and II only
B. I and III only
C. II and III only
(D.) I, II and III

19. Which species are a conjugate pair according to the Brønsted-Lowry theory?

A. CH_3COOH and CH_3CHO
B. NH_3 and BF_3
C. $H_2NO_3^+$ and NO_3^-
(D.) H_2SO_4 and HSO_4^-

20. Which is **not** a strong acid?

A. Nitric acid
B. Sulfuric acid
(C.) Carbonic acid
D. Hydrochloric acid

HL Questions: The following questions 21 – 31 are HL level questions

21. Which is a buffer solution?

I. 0.01 mol dm^{-3} HCl, 0.01 mol dm^{-3} NaCl STRONG ACID & IT'S SALT

II. 0.01 mol dm^{-3} CH_3COOH, 0.01 mol dm^{-3} CH_3COONa WEAK ACID & IT'S SALT

A. I only
(B.) II only
C. Both I and II
D. Neither I nor II

↙ for buffers.

(Total 1 mark)

22. The K_a value for an acid is 1.0×10^{-2}. What is the K_b value for its conjugate base?

A. 1.0×10^{-2}
B. 1.0×10^{-6}
C. 1.0×10^{-10}
(D.) 1.0×10^{-12}

$K_a \times K_b = K_w$

$1\times10^{-2} \times K_b = 1\times10^{-14}$

$K_b = 1\times10^{-12}$

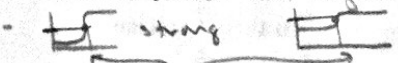
(Total 1 mark)

23. Separate 20.0 cm^3 solutions of a weak acid and a strong acid of the same concentration are titrated with NaOH solution. Which will be the same for these two titrations?

I. Initial pH
II. pH at equivalence point
III. Volume of NaOH required to reach the equivalence point

A. I only
(B.) III only
C. I and II only
D. II and III only

I - A strong acid has a lower pH (fully dissociated)
A weak acid has a higher pH (in equilibrium).

II -  strong weak (different pH)

III - look close - same volume needed.

(Total 1 mark)

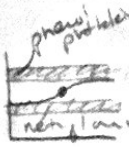
24. An acid-base indicator, HIn, dissociates according to the following equation.

$HIn(aq) \rightleftharpoons H^+(aq) + In^-(aq)$
colour A colour B

Which statement about this indicator is correct?

I. In a strongly acidic solution colour B would be seen.
II. In a neutral solution the concentrations of HIn(aq) and In^-(aq) must be equal.
III. It is suitable for use in titrations involving weak acids and weak bases.

A. I only
B. II only
C. III only
(D.) None of the above



I - In strongly acidic → HIn dominates.
II - only true for equal concentrations of SA/SB.
III - usually miss the equivalence point.

(Total 1 mark)

25. Which compound, when dissolved in aqueous solution, has the highest pH?

A. NaCl — BASE NaOH (S) — ACID HCl (S) → Neutral
(B.) Na_2CO_3 — NaOH (S) — H_2CO_3 (W) → strong base, weak acid. (BASIC)
C. NH_4Cl — NH_3 (W) — HCl (S) → Acidic
D. NH_4NO_3 — NH_3 (W) — HNO_3 (S) → Acidic

(Total 1 mark)

26. Which neutralization reaction could use phenolphthalein (pK_a = 9.3) and not methyl orange (pK_a = 3.7) as an indicator?

A. NaOH(aq) and ~~HNO_3(aq)~~ SA
B. ~~NH_3(aq) and CH_3COOH(aq)~~ BOTH WEAK
(C.) NaOH(aq) and CH_3COOH(aq)
D. NH_3(aq) and ~~HNO_3(aq)~~ SA

WANT pKa = 9.3 → must be basic or w/ strong base

DON'T WANT pKa = 3.7 → can't use strong acid

(Total 1 mark)

→ SB/WA = Basic solution. pKa 9.3 works, but pKa 3.7 would not.

27. An experiment was carried out to determine the concentration of aqueous ammonia by titrating it with a 0.150 mol dm^{-3} sulfuric acid solution. It was found that 25.0 cm^3 of the aqueous ammonia required 20.1 cm^3 of the sulfuric acid solution for neutralization.

(a) Write the equation for the reaction and calculate the concentration, in mol dm^{-3}, of the aqueous ammonia.

b/c diprotic acid.

$2 NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$

or

$NH_4OH + H_2SO_4 \rightarrow (NH_4)_2SO_4 + 2 H_2O$

$2 \times M_A V_A = M_B V_B$

$2(0.150\,M)(20.1\,mL) = M_B(25.0\,mL)$

$M_B = 0.241\,M$ **(4)**

(b) Several acid-base indicators are listed in Table 16 of the Data Booklet. Identify **one** indicator that could be used for this experiment. Explain your answer.

NH_3 or NH_4OH (Weak Base) H_2SO_4 (Strong Acid) => Will reach equilibrium @ pH < 7

∴ Methyl Red/Orange or Bromocresol Blue/Green. **(3)**

(c) (i) Determine the pOH of 0.121 mol dm^{-3} aqueous ammonia (pK_b = 4.75).

Weak base, so must use ICE chart and assumption to quadratic.

$-pK_b = 4.75 = 1.78\times10^{-5} = \frac{[OH^-][NH_4^+]}{[NH_3]} = \frac{x^2}{0.121 - x} \overset{\text{Assumption}}{\approx} \frac{x^2}{0.121} = 1.78\times10^{-5}$

$(0.121 / 1.78\times10^{-5} > 1000)$

$x = [OH^-] = 1.47\times10^{-3}$

$-\log[OH^-] = 2.83 = pOH$ **(4)**

(ii) State what is meant by the term *buffer solution*, and describe the composition of an acid buffer solution in general terms. A solution which resists change in pH (or changes in pH very slightly) when small amounts of acid a base are added. The composition would be: Weak Acid + Salts OR Weak Acid + Conj. Base. **(3)**

(iii) Calculate the pH of a mixture of 50.0 cm^3 of 0.100 mol dm^{-3} aqueous ammonia and 50.0 cm^3 of 0.0500 mol dm^{-3} hydrochloric acid solution.

$0.100\,M\ NH_3 = \frac{x\ mol}{0.050\,L} \Rightarrow 0.00500\ mol\ NH_3$

$0.0500\,M\ HCl = \frac{x\ mol}{0.050\,L} \Rightarrow 0.00250\ mol\ HCl$

½ of the NH_3 is neutralized, so 0.00250 left as NH_3 and 0.00250 now as NH_4^+ **(4)**

(Total 18 marks)

$pK_b = 4.75 \quad 10^{-4.75} = 1.78\times10^{-5} = K_b = \frac{[NH_4^+][OH^-]}{[NH_3]} = OH^-$ (cancel b/c equal amounts)

$-\log(OH^-) = pOH = 4.75$

$pH = 9.25$

28. (a) Predict and explain, using equations where appropriate, whether the following solutions are acidic, alkaline or neutral.

(i) 0.1 mol dm^{-3} $FeCl_3$(aq)

Salt — Acidic

C. Base: $Fe(OH)_2$ or $Fe(OH)_3$ = Weak Base

C. Acid: HCl = Strong Acid.

(1)

(ii) 0.1 mol dm^{-3} $NaNO_3$(aq)

Salt — Neutral

C. Base: NaOH = Strong Base

C. Acid: HNO_3 = Strong Acid

(1)

(iii) 0.1 mol dm^{-3} Na_2CO_3(aq)

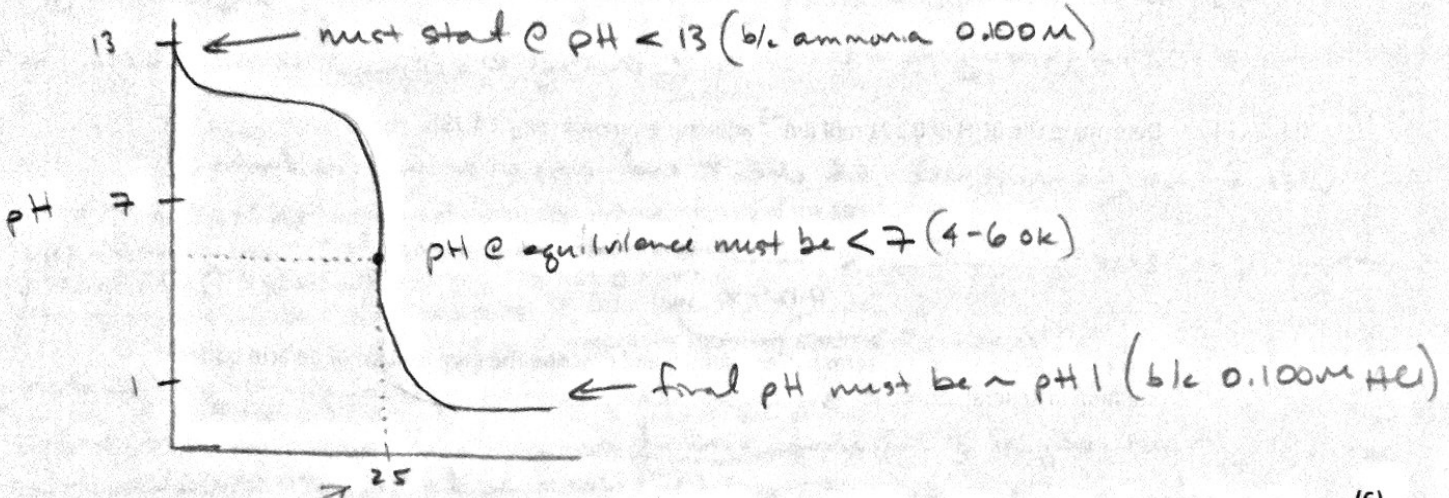
Salt + Basic — C. Base NaOH = Strong Base; C. Acid H_2CO_3 = Weak Acid

(1)

(Total 3 marks)

29. 0.100 mol dm^{-3} hydrochloric acid solution is added to 25.0 cm^3 0.100 mol dm^{-3} ammonia solution and the pH is recorded until a total of 35.0 cm^3 hydrochloric acid has been added.

(i) Sketch a graph to show how the pH changes as hydrochloric acid is added to the ammonia solution. Use a pH scale of 0–14, and an acid volume scale of 0–35 cm^3. Explain the shape of the curve.



(6)

$NH_4OH + HCl \rightarrow NH_4Cl + H_2O$

WB SA salt water

will be an equivalence @ acidic conditions

(ii) Use table 17 of the Data Booklet to suggest an indicator that could be used in the titration, explaining your choice.

Methyl orange / Red

Bromothymol Blue

Bromocresol green

pKa of indicator around pH @ equivalence UR

@ end point UR indicator pH range falls where there is a sharp pH change.

(2)

(Total 8 marks)

30. With reference to Table 16 in the Data Booklet, determine the pH of a 0.100 mol dm^{-3} solution of propanoic acid. (hint: which I shouldn't give, use ICE chart)

pKa (propanoic acid) = 4.87 $10^{-4.87} = 1.35 \times 10^{-5}$

$1.35 \times 10^{-5} = K_a = \frac{[CH_3CH_2COO^-][H^+]}{[CH_3CH_2COOH]} = \frac{x^2}{0.100 - x} \overset{\text{Assumption}}{\approx} \frac{x^2}{0.100} = 1.35 \times 10^{-5}$

$[H^+] = x = 1.16 \times 10^{-3}$

(Total 3 marks)

$-\log[H^+] = 2.94$